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The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Assistant Dean for MSN and DNP Studies, on behalf of the program; we verify that this is the final, approved version of the student's DNP Project including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Kandace Vanhoozer, Student

Dr. Sheila Melander, Advisor

DNP Final Project Report

The Effect of an Educational Intervention on the Blood Culture
Contamination Rate in Acutely Ill Adults

Kandace Vanhoozer

University of Kentucky

College of Nursing

Spring, 2018

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Dedication

My DNP project is dedicated to my friends and family who have been so understanding and supportive during this period of my life. To my mom, for always being my biggest cheerleader, believing in me oftentimes more than I believe in myself, and for her endless guidance when I called her to vent about frustrations as well as fears. To my dad, for loving me despite choosing to go to the rival school of his favorite college sports team and for not writing me out of his will because of it. To my brother, for always encouraging me to be the best version of myself. To my best friend, Tara, for listening to me talk endlessly about school and clinical plans and never once got tired of hearing about it (or at least never admitted that she did). Finally, to my niece Ava, who I hope will one day look at me as a role model and know that she is capable of anything she puts her mind to.

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Abstract

PURPOSE: The purpose of this project was to assess the knowledge of nurses that collect blood culture specimens at University of Louisville Hospital and to implement an educational intervention among those nurses. It was expected that the educational intervention implemented for this project would increase nurses' knowledge regarding the proper technique for blood culture specimen collection and decrease in the rate of contaminated blood cultures.

METHODS: This study included a prospective pre- and post-test of nursing knowledge followed by an educational intervention as well as a retrospective comparison of the pre- and post-education blood culture contamination rates.

RESULTS: Of the 23 nurses that were eligible, 19 (82.6%) consented to participate in the educational intervention. The mean score of the pre-test was 9.7 and the mean score of the post-test was 13.5, indicating an increase in knowledge ($p < .001$). In the pre-education group the medical records of 70 patients over 110 admissions were reviewed from July 16, 2017 to October 18, 2017. In the post-education group the medical records of 91 patients over 123 admissions were reviewed from October 19, 2017 to January 18, 2018. The pre-education blood culture contamination rate was 1.9% and the post-education contamination rate was 0.4% ($p = .312$).

CONCLUSION: A simple and inexpensive educational intervention can increase the knowledge among nurses that collect blood culture specimens. While the reduction in the contamination rate is not statistically significant, it is clinically significant with a cost avoidance of approximately \$11,200 over the three month post-education period. The results of the pre- and post-test could be used to tailor future educational interventions and a retrospective analysis for a longer duration could include enough patients to yield statistically significant results.

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The Effect of an Educational Intervention on the Blood Culture

Contamination Rate in Acutely Ill Adults

Background

Bacteremia, bacteria present in the bloodstream, affects around 200,000 patients every year with a mortality rate ranging from 14% to 37% (Coburn, Morris, Tomlinson, & Detsky, 2012; Long & Koyfman, 2016). Blood stream infections (BSIs) are the 10th leading cause of death in the United States (Roque et al., 2012), making them an issue of importance for hospital care. Blood cultures are the diagnostic test of choice to detect BSIs. However, it is estimated that only 10% of blood cultures are positive, with as many as half being false positive results due to contamination (Roque et al., 2012) leading to negative impacts on patients.

Not only does this call the utility of blood cultures for detection of bacteremia into question, but false positive blood cultures also have negative impacts on patients in the acute care setting such as unnecessary antimicrobial use, repeat testing, increased length of stay (LOS), and increased costs (Santos et al., 2018). Blood culture specimens are most often contaminated with skin flora and contamination typically occurs when the specimen is being collected (Hossain et al., 2016) due to improper aseptic technique when obtaining a specimen by venipuncture and inadequate sterilization when collecting specimens from central venous access devices (CVADs; Santos et al., 2018). Therefore, it is vital that proper technique for specimen collection becomes a top priority among individuals that collect blood culture specimens.

After a merge into a larger healthcare system, numerous employees at University of Louisville Hospital (ULH) were laid off, including phlebotomists. The subsequent reduction in phlebotomy staff led to some in-patient units to begin to allow blood culture collection to be performed by nurses. According to Dr. James Snyder, the Director of Microbiology at ULH,

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prior to the merge the rate of contaminated blood culture specimens facility-wide was less than 2%, below the target rate of 3% as recommended by the Clinical and Laboratory Standards Institute (J. Snyder, personal communication, February 15, 2017).

Dr. Snyder added that, in early 2017, the rate of contaminated specimens had increased to greater than 12% (J. Snyder, personal communication, February 15, 2017). Facilities that utilize dedicated phlebotomists for blood culture collection have a significantly lower rate of contamination when compared to facilities in which non-laboratory staff collect specimens (Bekeris, Tworek, Walsh, & Valenstein, 2005; Snyder et al., 2012). Nurses are less likely to comply with protocols for collection of blood culture specimens due to having many other clinical duties (Al-Hamad et al., 2016). It is likely that the increase in the rate of contamination at ULH resulted from the decrease in phlebotomy staff and the increase in nurses collecting blood culture specimens.

Each contaminated specimen carries a cost of approximately \$5,600 in additional treatment for patients at ULH (J. Snyder, personal communication, February 15, 2017). The increased cost is consistent with current literature on the topic. For example, Zwang and Albert (2006) found that a false positive rate of 6% translated to an approximate annual facility-wide cost of \$1.4 to \$1.8 million. Hence, it is imperative that the rate of contamination is minimized in order for blood culture testing to be considered cost-effective.

To promote proper technique related to blood culture specimen collection in an effort to reduce contamination, educational interventions have been examined. Current literature demonstrates that educational interventions are effective in reducing blood culture contamination rates (Alhamadi et al., 2015; Al-Hamad et al., 2016; Park, 2015; Ramirez et al., 2015; Robert, 2011; Robertson, Russell, & Inverarity, 2013; Roth et al., 2010). For example, Al-Hamad et al.

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(2016) examined the effect of an educational intervention on the rate of blood culture contamination by comparing the six months pre-education to the six months post-education and found a 36% reduction. The use of an educational intervention targeted toward proper blood culture specimen collection can not only reduce contamination rates, but can also decrease costs (Alhamadi et al., 2015; Al-Hamad et al., 2016, & Robertson et al., 2013) and LOS (Robert, 2011).

Theoretical Framework

The theory that guided the research for this study was Lewin's Change Management Theory, a theory that is commonly used among nurses to create change at the bedside (Wojciechowski, Pearsall, Murphy, & French, 2016). It focuses on understanding the negative forces that maintain the status quo and the positive forces that allow change to take place. This model consists of three steps. Step one is unfreezing. This step creates awareness of the problem and makes it possible to let go of old ways and patterns and can include demonstration of the problem and education. Next, step 2 is movement. This step involves seeking new alternatives, demonstrating the benefits of change, and attempting to minimize negative forces that prevent change from taking place. This step can include education, coaching, and training. Finally, step 3 is refreezing in which changes are integrated and become the new norm. It includes celebrating successes, re-training, and monitoring key performance indicators (Wojciechowski et al., 2016).

Lewin's Change Management Theory was used in the context of this study in the following ways. First, step 1 occurred with the realization of the increase in the contamination rate and the negative impacts it has on patient outcomes as well as cost. Next, step 2 occurred with educating a select group of nurses on the proper technique for blood culture specimen collection. Finally, step 3 will occur by sharing study results with the nursing staff, continuing to

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monitor contamination rates, and using the study findings to identify opportunities for continued education

Purpose and Objectives

The purpose of this project was to assess the knowledge of nurses who collect blood culture specimens and to implement an educational intervention for nurses who collect blood cultures at ULH in order to decrease the rate of contamination. We expected that the educational intervention implemented for this project would:

1. Increase nurses' knowledge regarding the proper technique for blood culture specimen collection.
2. Decrease in the rate of contaminated blood cultures.

Methods

Setting

The study was performed at ULH, a 404 bed Academic Medical Center and Level I Trauma Center, located in Louisville, Kentucky. The study took place on the Bone Marrow Transplant Unit (BMTU) where nurses have the ability to collect blood culture specimens when a patient is found to be hyperthermic upon assessment. Per the fever protocol, nurses collect blood culture specimens via venipuncture as well as from CVADs including ports, peripherally inserted central catheters (PICCs), tunneled catheters, and non-tunneled catheters. The BMTU is the only unit in the hospital that allows nurses to obtain blood culture specimens by venipuncture as well as from CVADs and is the reason why this unit was chosen for the study setting.

Study Design

A prospective design in the form of a pre- and post-test was used to assess knowledge of blood culture specimen collection among nurses. Between the pre- and post-tests an educational

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intervention was provided in the form of verbal explanation and demonstration. After the educational intervention, a retrospective design examined patient data that were obtained from electronic health records secured on Cerner, the current electronic health record system used at ULH.

Despite the post-education arm of the study being prospective, all blood culture specimens collected during the study period needed to be available to adequately compare the pre- and post-education contamination rates; therefore, patient consent was not obtained and all patient data were collected and analyzed retrospectively. The Cerner database was queried for patients on the BMTU who were admitted during the study period. The medical records for those patients were then reviewed to evaluate the results of all blood cultures collected during the study period in order to determine the rate of contamination.

Sample

All 23 registered nurses who were employees of the BMTU were eligible to participate in the study; there were no exclusion criteria. To examine the effect of the educational intervention on the blood culture contamination rate, electronic data for all patients admitted to the BMTU during the study period were examined. The pre-education period included the three months prior to the intervention and the post-education period included the three months after the intervention. Records included in the data analysis were from patients aged 18-90 years who had a blood culture specimen collected during the study period, from July 16, 2017 to January 18, 2018. All blood cultures collected during the study period were examined. Other than meeting the age requirement, there were no exclusion criteria for patients in this study.

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Data Collection

This study included nurses from the BMTU and began with a pre-test of nurses' knowledge regarding blood culture specimen collection. The pre- and post-test were identical, included 15 questions, and were developed from the current policy at ULH regarding blood culture collection. The tests were distributed to the nurses and returned to the principal investigator before and after the educational intervention.

The blood culture contamination rates were compared three months prior to and three months after the educational intervention was completed in order to assess the effect of the educational intervention. Patient records were accessed using the Cerner database and all blood cultures for patients who met the inclusion criteria collected during the study period were examined. Contamination rates were based on the number of blood cultures that were contaminated out of the total number of blood cultures collected in the specified time points. Contaminated blood culture specimens are defined as: any one of the following skin organisms that is recovered in only one culture in the setting where multiple (two or more) cultures have been collected: coagulase-negative staphylococci, *Corynebacterium* species, *Bacillus* species other than anthracis, *Propionibacterium acnes*, and/or micrococcus.

The Cerner database does not have the functionality to tease out specific patients who had blood cultures drawn during a specific period of time. Therefore the Cerner database was queried for all patients admitted to the BMTU during the study period, and the results of all blood culture specimens that were collected during the study period were evaluated.

Data Analysis

The pre- and post-tests consisted of 15 multiple choice and true/false questions and were developed using the current policy at ULH regarding blood culture collection. Each correct

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answer was scored as a 1 and each incorrect answer was scored as a 0 with the lowest cumulative score being 0 and the highest cumulative score being 15. The mean score of the questions demonstrates knowledge of blood culture specimen collection with greater scores representing greater knowledge. The change in knowledge regarding the collection of blood specimens before and after the educational intervention was determined using a paired sample t-test.

Blood culture contamination rates were based on the number of blood cultures that were contaminated out of the total number of blood cultures collected in the specified time point. This measure was collected for the period three months prior and three months after the intervention. An independent sample t-test was used to compare the changes in contamination rates pre- and post-education.

Results

Nursing Knowledge

Of the 23 nurses that are employees of the BMTU, 19 nurses consented to participate in the educational intervention, for a participation rate of 82.6%. The educational intervention took place during annual competency evaluations for oncology staff on October 16, 2017 and October 18, 2017. All of the oncology nurses were required to attend competency evaluations. However, any nurse that participated in the competency evaluations as a validator was not required to have their skills validated.

Figure 1 shows the comparison of the frequency of missed questions between the pre-test and the post-test and Table 2 shows the comparison of incorrect answer percentages between pre- and post-test. The most frequently missed questions on the pre-test were question numbers 1, 3, 4, 14, and 15. Those questions were as follows:

- 1.) What is necessary for adequate skin disinfection prior to venipuncture?

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- 3.) How long should you allow the site to dry prior to obtaining blood for culture?
- 4.) The minimum volume per blood culture bottle is ____ml. The maximum is ____ml.
- 14.) Once the appropriate number(s) of blood cultures have been collected, additional cultures should not be obtained for at least ____ hours.
- 15.) Avoid drawing from a PICC line involving heparin because heparin has antibacterial properties (true or false).

The most frequently missed questions on the post-test were question numbers 4 and 9. Those questions were as follows:

- 4.) The minimum volume per blood culture bottle is ____ml. The maximum is ____ml
- 9.) If a culture is obtained from a central venous access device, when should a peripheral blood culture be obtained?

It is important to note that questions 9 and 11 had a higher percentage of incorrect answers on the post-test when compared to the pre-test. Both questions related to the timing of blood culture collection. The results of the pre- and post-test can be used to tailor future educational opportunities, which will be discussed in the recommendations for practice section.

As previously mentioned, each correct answer was scored as a 1 and each incorrect answer was scored as a 0, with a higher score representing greater knowledge. Table 1 shows the mean score and standard deviation for both the pre- and post-test. The mean score of the pre-test was 9.7 and the mean score of the post-test was 13.5. The increase in the post-education mean score indicates an increase in nursing knowledge after the educational intervention. Statistical significance was determined using a paired sample t-test with $p < .001$, representing a statistically significant increase in nursing knowledge after education.

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Blood Culture Contamination

Table 3 shows a comparison of the data regarding blood culture specimens that were collected during the study. The pre-education period included the results of blood culture specimens collected by registered nurses, as well as phlebotomists, from July 16, 2017 to October 18, 2017. The medical records of 70 patients over 110 admissions were reviewed. There were 159 blood culture sets collected during the pre-education period, with 27 having positive results. The percent of positivity (the number of positive cultures divided by the total number of cultures collected) for the pre-education period was 16.9%.

Of the 27 positive cultures, three were identified as being contaminated for a contamination rate (the number of contaminated specimens divided by the total number of cultures collected) of 1.9%. The organisms identified in the three contaminated specimens were streptococcus vestibularis, streptococcus salivarius and staphylococcus epidermis, and Propionibacterium acnes. These specimens were collected by a registered nurse by peripheral stick, a registered nurse with site of collection not specified, and a phlebotomist by peripheral stick, respectively.

The post-education period included the results of blood culture specimens collected by registered nurses, as well as phlebotomists, from October 19, 2017 to January 18, 2018. The medical records of 91 patients over 123 admissions were reviewed. There were 223 blood culture sets collected during the post-education period, with 37 having positive results. The percent of positivity for the post-education period was 0.166 or 16.6%, which is comparable to the percent of positivity for the pre-education period.

Of the 37 positive cultures collected in the post-education period, only one was identified as being contaminated for a contamination rate of 0.4%. The organism identified in the

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contaminated specimen in the post-education period was staphylococcus epidermis and the specimen was collected by a phlebotomist by peripheral stick. There were no identified contaminated specimens collected by a registered nurse in the post-education period.

Due to the small sample size, the changes in contamination rates pre- and post-education were compared using a Fisher's Exact Test with $p = 0.312$, indicating that the change in rates was not statistically significant. While the change in contamination rates did not yield statistically significant results, the reduction is clinically significant in terms of cost avoidance which will be discussed in the next section.

Discussion

Study Objectives

Both of the objectives for the study were met; there was an increase in knowledge among nurses after the educational intervention, as evidenced by the higher mean score for the post-test of nursing knowledge when compared to the pre-test results, as well as a decrease in the rate of contaminated blood culture specimens. However, it is important to note that causality can't be suggested in a pre- and post-test design with a small sample size. This study reflects current literature that a simple and inexpensive educational intervention can lead to a reduction in blood culture contamination rates. However, the rate of contamination during the pre-education period may have been higher, which could have resulted in an even greater reduction in the contamination rate.

Transition to New BMTU

During data collection a confounding variable was identified. Near the end of the pre-education period a new BMTU was opened and, prior to patients being transferred to the new unit, they were dispersed between two other units. There was no way to retrospectively identify

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patients on the two other units who were BMTU patients and, although nursing staff from the BMTU were floated to both units, there was no way to verify that all of the BMTU patients were being cared for exclusively by BMTU nursing staff. Therefore, the blood culture specimen results during this transition period were not included in the pre-education data leading to the pre-education sample not being representative of all of the patients admitted to the BMTU during that study period.

Cost Avoidance

Direct costs associated with a decrease in the rate of contamination were not evaluated with this study, therefore only potential cost avoidance was reported. At ULH, each contaminated specimen carries a cost of approximately \$5,600 in additional treatment. While the pre-education contamination rate was lower than the acceptable 3%, decreasing the total number of contaminated blood cultures in the post-education period by two could lead to a potential cost avoidance of \$11,200 over the three month post-education period.

If this reduction of contaminated specimens is maintained for a year, the potential cost avoidance, for one unit, would be \$44,800. If these results were repeated in the seven other intensive care units at ULH the potential cost avoidance would be \$313,600 in one year. Additional cost avoidance would be possible if the number of contaminated specimens are reduced by greater than two within a three month period.

Limitations

There were limitations to this study. First, the results of this study are not generalizable as it had a small sample size, was conducted at a single site, and included a very specific patient population. The transition to a new unit during the pre-education period is also a limitation because the pre-education patient data are not a representative sample of all of the patients

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admitted to the BMTU during that period of the study. Another limitation is that direct costs were not evaluated. Cost analysis was based on the estimated cost avoidance, related to the reduction in the number of contaminated specimens, and direct costs were not evaluated. The actual cost savings for reducing the rate of contamination in bone marrow transplant patients may vary, as they are a highly specialized group of patients.

Recommendations for Practice

Based on the frequently missed questions from both the pre- and post-test, as well as the blood culture specimen results, there are numerous opportunities for continued education. Throughout the study period, including both pre- and post-education data, there were a total of 382 blood culture sets collected. Of the 382 total sets, 212 were drawn by registered nurses, representing 55.5% of all cultures collected. Of the 212 sets collected by nurses, 147 (69.3%) did not have a site of collection identified. All registered nurses that collect blood culture specimens should be educated on the importance of identifying the site from which a blood culture was collected.

Identification of the site is important information that needs to be available for providers to determine a plan of care for the patient. Oncology patients are a particularly sensitive group, as they are at an increased risk for developing infections due to being immunocompromised and their burden of comorbidities (Mollee et al., 2011). Many oncology patients require CVADs for treatment. Blood cultures obtained from CVADs may provide clinically useful information that warrants further evaluation (Desjardin et al., 1999). Additionally, blood cultures collected from CVADs are necessary in order to identify or rule out colonization with bacteria, in which the CVAD may need to be removed and replaced (Snyder et al., 2012). However, if the site that a

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blood culture is obtained from is not listed, decisions related to patient care can be delayed as additional cultures may need to be collected.

Next, all registered nurses should be educated on the importance of the volume obtained in culture bottles. Blood volume is the single most important factor for determining sensitivity of a blood culture and identifying microorganisms (Garcia et al., 2015; J. Snyder, personal communication, February 28, 2018). On both the pre- and post-test, one of the most frequently missed questions was in regard to the minimum and maximum volume per blood culture. It is important to ensure that those collecting blood culture specimens understand the importance and necessity for obtaining the proper amount of blood per culture.

Additionally, because they collect blood cultures from both peripheral stick and from CVADs, the nurses from the BMTU should be educated on timing between cultures from different sites and the concept of differential time to positivity. When a CVAD is the source of infection, the concentration of microorganisms present in the culture sent from the CVAD will be higher than the concentration in a specimen collected from peripheral stick (Al-Juaid, Walkty, Embil, Crockett, & Karlowsky, 2012). This leads to the culture that was obtained from the CVAD showing positive results faster than the culture that was obtained by peripheral stick. Differential time to positivity takes into account how long it takes a blood culture that was collected from a CVAD to show positive results when compared to a peripheral blood culture collected around the same time. If the CVAD culture shows positive results two or more hours before the peripheral culture, it is likely that the CVAD is the source of the BSI. Differential time to positivity reportedly has a sensitivity of 90% and a specificity of 72 – 87% in terms of detecting a BSI from a CVAD (Al-Juaid et al., 2012).

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Many of the nurses that participated in the educational intervention were unaware of the current contamination rate and increased costs associated with contamination at ULH. It is important that the nursing staff is educated on what the contamination rate is because, if they are informed, they would be more likely to be engaged and actively participate in efforts to decrease the contamination rate. It would even be beneficial to inform the nurses of their individual performance regarding blood culture contamination during annual performance reviews because they may feel more empowered to take action when it is tied to their job performance.

Nurses from the seven other intensive care units throughout the hospital collect blood culture specimens, but only from CVADs. Specimens obtained from CVADs are more likely to be contaminated; the presence of bacteria on the surface of the lumens of the catheter is not always clinically significant because it does not necessarily signify bloodstream infection (Santos et al., 2018). It is vital that the registered nurses in other intensive care units receive education and training on proper techniques for specimen collection.

However, nurses are not the only group that should receive annual education and training, as phlebotomists primarily collect blood cultures on all of the other units throughout the hospital. One of the contaminated cultures collected during the pre-education period and the only contaminated culture collected in the post-education period were collected by phlebotomists. This demonstrates the importance for annual education to be extended to phlebotomy staff as well. Providing education to other nurses and phlebotomists that collect blood culture specimens could further decrease the blood culture contamination rate throughout the facility, leading to better patient outcomes and decreased costs.

Based on the frequently missed questions on the pre- and post-tests, there is an opportunity to monitor for adherence to the protocol for blood culture specimen collection.

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Adequate disinfection, dry time after disinfection, not palpating the site after it is cleaned, and adequate blood volume are vital in decreasing the probability of contamination as well as identifying microorganisms. A simple way to ensure that these elements of the protocol are being adhered to is to monitor adherence in real time. This can be done for nurses as well as phlebotomists when a blood culture specimen is being collected. The audits could be completed on a random basis to encourage every staff member who obtains blood cultures to perform the task properly every time.

Recommendations for Future Studies

The sample for this study was not large enough to yield statistically significant results. In order to determine if the change in contamination rates pre- and post-education is statistically significant, the sample needs to include more patients. This can be done by retrospectively comparing the pre- and post-education data for a longer duration of time in order to compare a larger sample to evaluate for statistical significance. However, with the pre-education contamination rate being so low, an additional study would likely need to be a multicenter study in order to capture enough patients to have sufficient power to generate significant findings.

This study did not evaluate the effect of decreasing contamination rates on patient outcomes or costs. A retrospective study could be used to evaluate the impact that reducing the blood culture contamination rate has on length of stay and costs of treatment as well as cost avoidance.

Conclusion

Bacteremia affects hundreds of thousands of patients annually with a mortality rate as high as 37%. Blood cultures are the diagnostic test of choice to detect BSIs. However, it is estimated that only 10% of blood cultures are positive, with as many as half being false positive

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results due to contamination leading to unnecessary antimicrobial use, repeat testing, increased costs, and increased length of stay. Contamination typically occurs when specimens are collected or processed. The use of an educational intervention targeted toward proper blood culture specimen collection can lead to a reduction in contamination rates.

This study implemented an educational intervention among nurses who collect blood culture specimens in an Academic Medical Center and Level I Trauma Center and compared the contamination rates three months pre- and post-education. While the reduction in the blood culture contamination rate was not statistically significant ($p=0.312$), it is clinically significant due to cost avoidance. This study also examined nursing knowledge using a prospective pre- and post-test design and there was a statistically significant increase in nursing knowledge after the educational intervention ($p<.001$). This highlights the importance of including other staff members that collect blood cultures in future educational interventions in order to further reduce the rate of contamination.

While causality can't be assumed in a pre- and post-test design with a small sample size, the results of the pre- and post-tests could be used to tailor future educational interventions. A retrospective analysis for a longer duration of time could include enough patients to yield statistically significant and more generalizable results.

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Table 1. *Comparison of knowledge pre and post-educational intervention (N=19)*

	Pre-education	Post-education	<i>p</i>
	Mean (SD)	Mean (SD)	
Knowledge	9.7 (1.6)	13.5 (1.1)	<.001

Table 2. *Comparison of incorrect answer percentages on pre- and post-test*

Test Question	% Pre-education incorrect	% Post-education incorrect
1.) What is necessary for adequate skin disinfection prior to venipuncture?	52.6%	0%
2.) In order to properly prep the selected site for venipuncture, the site should be scrubbed in a back and forth motion, prepping an area of what size?	36.8%	0%
3.) How long should you allow the site to dry prior to obtaining blood for culture?	57.9%	21%
4.) The minimum volume per blood culture bottle is ____ml. The maximum is ____ml.	63.1%	31.6%
5.) The _____ bottle should be inoculated first.	26.3%	0%
6.) If more than 5ml of blood cannot be obtained, inoculate the _____ bottle only.	31.6%	0%
7.) Who can obtain blood from a central venous access device for culture?	43.6%	21%
8.) Select the correct sequence of actions prior to inoculating the blood culture bottle(s):	31.6%	10.5%
9.) If a culture is obtained from a central venous access device, when should a peripheral blood culture be obtained?	15.8%	36.8%
10.) Blood collected from	5.3%	0%

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indwelling devices are more likely to be contaminated by organisms residing in the device itself or device components.		
11.) If two sets are ordered, they should be drawn from 2 separate sites within 1 hour of each other.	10.5%	15.8%
12.) When prepping the site for venipuncture, the site should be scrubbed for _____ seconds.	31.6%	10.5%
13.) It is okay to palpate the site after it has been prepped.	10.5%	10.5%
14.) Once the appropriate number(s) of blood cultures have been collected, additional cultures should not be obtained for at least _____ hours.	68.4%	0%
15.) Avoid drawing from a PICC line involving heparin because heparin has antibacterial properties.	52.6%	0%

Table 3. *Comparison of pre- and post-education blood culture data*

	Pre-education	Post-education
Blood culture sets	159	223
Positive blood cultures	27	37
Percent of positivity (# of positive/total collected)	16.9%	16.6%
Contaminated blood cultures	3	1
Contamination rate (# of contaminated/total collected)	1.9 %	0.4 %

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Figure 1. *Comparison of Pre- and Post-Test Incorrect Answer Frequencies*

